CRATER SIZE-FREQUENCY DISTRIBUTION ON VENUS: VARIATIONS WITH ELEVATION.

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Introduction. There are about a thousand impact craters on Venus. They are known to be rather uniformly distributed over the Venus surface [1]. Deviation of crater hypsometry from surface hypsometry is not confident [2]. However there is significant increase in relative number of modified craters with elevation [3]. In this paper, dependence of crater size-frequency distribution on elevation is examined. Significant variations are revealed and interpreted.

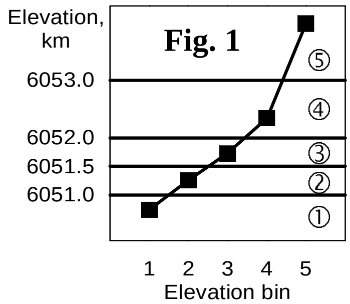

Fig. 1

Observations. In this study the data base on Venus impact craters prepared at LPI [3] was used. Use of the USGS data base [4] leads to the same results. All impact craters from the data base having estimations of their elevations (totally about 90% of craters) were divided into 5 elevation bins. The bin boundaries are levels of 6051, 6051.5, 6052 and 6053 km of planetary radius. These levels and mean elevations of all craters in each bin are shown in the **Fig. 1**. Number of craters in the bins is shown in the **Fig. 2**.

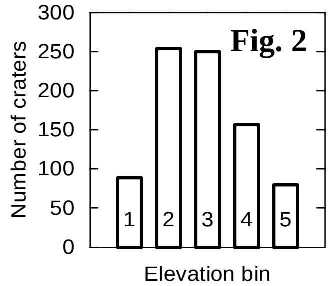

Fig. 2

Mean crater diameter for the bins is plotted in the **Fig. 3** (circles). It is clearly seen that mean crater diameter in the lowlands (bin *1*) is remarkably smaller than planetary average, while for bin *4* it is much larger.

Cumulative size frequency distribution $F(D)$ was calculated for each bin. ($F(D)$ is the percentage of craters with diameter > D.) **Fig. 4** shows the distribution for bin *1* (thin line) compared with the distribution for all craters (bold line). In **Fig. 5** such comparison is done with so-called P-P plot, in which $F(D)$ for bin *1* is plotted against $F(D)$ for all craters (bold curve). If there were no difference between the distributions, the plot would be a diagonal (thin line). Finally, **Fig. 6** presents such comparison for all bins with ΔP-P plots, where the difference between $F(D)$ for each bin and the global one is plotted against the global $F(D)$ (solid curves).

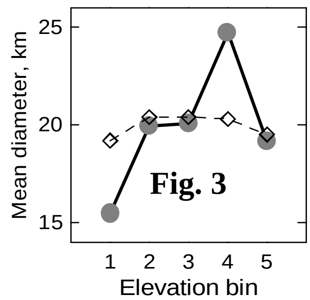

Fig. 3

It is clearly seen from **Fig. 6**, that for bins ***2*** and ***3*** the distributions do not differ significantly from each other and from the global distribution. For bin ***4*** the distribution is generally shifted toward *larger* diameters. For bin ***5*** the difference is not well defined, and stochastic variations are high because of smaller number of craters in this bin, but the deviation has the same signature. The deviation of the distribution for highlands is similar to and partly the same as the deficiency of small craters on tesserae noted in [5]. For bin ***1*** well-expressed opposite effect is observed. The distribution is shifted toward *smaller* diameters. Very roughly speaking, the main difference between the bin ***1*** distribution and the global one is the deficit of about 7 craters of diameter D = 32...46 km, and the excess of about 9 craters of D = 8...11 km.

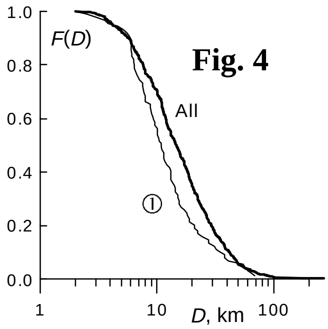

Fig. 4

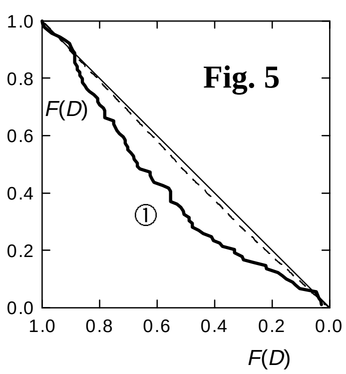

Fig. 5

The deviations for bins *1* and *4* are statistically significant. The Kolmogorov - Smirnov statistical test based on maximum deviation of cumulative distribution rejects stochastic nature of the difference at the confidence level of 0.95. The ω^2 statistical test based on RMS deviation of cumulative distribution does it on 0.97 confidence level.

Saying strictly, it is incorrect to compare the size-frequency distribution for each bin with the global distribution. "Elevation of an impact crater" means elevation of the impact site as if there were no crater. The procedure of derivation of this elevation leads to a bias for large craters, and as a result, to a bias of the size frequency distribution. To study this geometrical effect we applied the Monte-Carlo simulation. Simulated craters with the observed set of diameters were distributed randomly over the surface, then their elevations were calculated with the same procedure as in [3] using topography data [6]; and model size-frequency distribution for elevation bins was obtained. The distribution was averaged over a large number of model runs. Boxes in **Fig. 3** show the mean diameter for each bin. Dashed lines in **Fig. 5** and **Fig. 6** show deviation of the model distributions from the global one. The geometrical effect turns out to be noticeable for bins *1* and *5*, but the shift of model distribution is much smaller than observed shift. The differences between modeled and actual distribution for the bins *1* and *4* remain statistically significant.

Discussion. So, we observe relative deficiency of large and relative excess of small craters in the lowlands and the opposite trend on highlands. The deficiency of small craters at high elevations can be explained as an *observational effect* as it was done in

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[5], because elevated regions tend to bear many radar-bright features, e.g. tesserae, and some small craters cannot be identified as craters. The deviation of the distribution for lowlands (bin *1*) definitely cannot be explained in this way, because all bins *1-3* are dominated by plains. The effect for highlands might also be the same as for lowlands but with the opposite sign, at least partly. Below, the effect for lowlands is discussed. Venusian lowlands mostly coincide with plains basins described in [7]. Regarding stratigraphy units [8] lowlands are dominated by plains with wrinkle ridges, while the surface in bins *2* and *3* comprise all plain units.

What elevation-controlled factors can influence *crater emplacement*? Systematic changes in target rock mechanical properties with elevation can barely be strong enough to influence the size distribution so much. Atmospheric layer above lowlands is effectively 7% thicker than above typical plains. A projectile will lose part of its energy on its way trough the additional layer and form a smaller crater. It would lead to the observed effect. From the other hand the additional atmospheric layer would prevent formation of some smallest craters causing the opposite effect. The balance of these two factors and resulting dependence of the cratering rate on elevation is a subject of a special study. Rough estimations in the frame of some simplification of models from [9] showed that deviation of the distribution due to additional atmospheric layer is one order of magnitude smaller than observed. Thus influence of elevation on crater emplacement is minor.

It is easier to find explanation for the observed effect through specific *crater extinction* in lowlands. No crater extinction mechanism erases large craters more effectively than small, but it is natural, that some resurfacing processes erase small craters much more effectively than large. From this point of view, the observed relative excess of small craters on lowlands means that recent *resurfacing rate on lowlands is lower* than on typical plains from elevation bins *2* and *3*.

We can add some other evidences for this conclusion. (1) From one hand apparent crater degradation is known to correlate with regions of abundant volcanic and tectonic features [2, 3]. From another hand most of these features avoid lowest elevations [2]. (2) There are few embayed craters on lowlands. Identification of embayment is subjective, and the crater data bases [3,4] differ sufficiently in it. Relative number of embayed craters is small in both data bases, and for the USGS data base [4] this difference is statistically significant despite small total number of embayed craters. (3) Size-frequency distribution of embayed craters is shifted toward larger diameters in comparison to the distribution of all craters. **Fig. 7** demonstrates the deviation for both data bases with a P-P plot. The reason of the relative deficiency of small embayed craters is obvious: some small craters that would be embayed, if they were large, are plainly erased. Of course, some observational bias also can take place.

In other words, in respect to the resurfacing that erases all craters including large, the lowlands are *younger* than average other plains, while in respect to the renovation of small crater subpopulation, the lowlands are *older*. For craters larger than 20 km the mean crater density in lowlands is about 35% less than global. Corresponding age difference exceeds 8% at 0.95 confidence level.

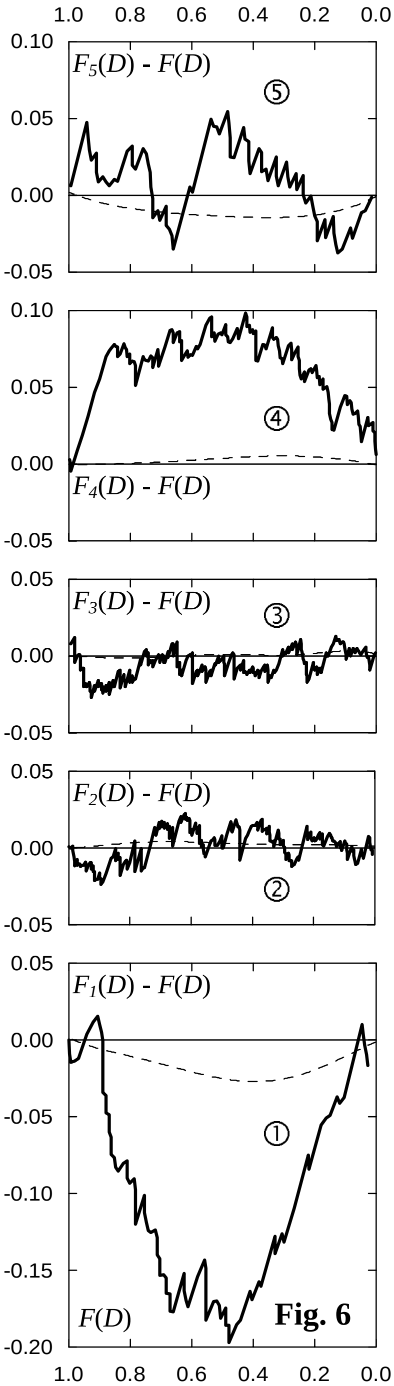

Fig. 6

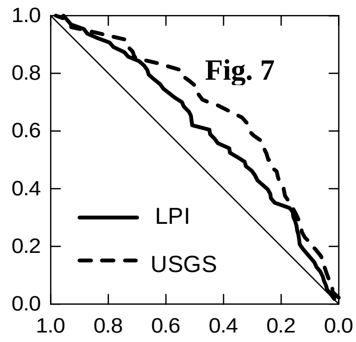

Fig. 7

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